A Timetree of Early Life on Earth

S. Blair Hedges
Department of Biology
The Pennsylvania State University
208 Mueller Laboratory, University Park, Pa, 16802
USA
sbh1@psu.edu

Jaime E. Blair
Department of Biology
The Pennsylvania State University
208 Mueller Laboratory, University Park, Pa, 16802
USA
jeb322@psu.edu

Fabia U. Battistuzzi
Department of Biology
The Pennsylvania State University
208 Mueller Laboratory, University Park, Pa, 16802
USA
fxb142@psu.edu

Most agree that our search for life elsewhere will benefit by a fuller understanding of how life arose and evolved on Earth. However, large gaps remain in our knowledge of such basic things as the relationships of living organisms (the tree of life) and their times of divergence. This is a particular problem for the Precambrian, which represents 88% of the history of the Earth (4.5-0.54 billion years ago, Ga) because life from that time period is poorly represented in the fossil record.

Genomes provide abundant sources of data for building trees and estimating divergence times. Our divergence time estimates from analyses of prokaryote genome sequences indicate that life arose prior to 4.1 Ga. Also, these data support an early origin of methanogenesis (3.8-4.1 Ga), consistent with models suggesting that methane was important in the early warming of the Earth's surface. However, these same data indicate that cyanobacteria appeared relatively late (~2.6 Ga) thus placing into question models of Earth history requiring biological production of oxygen in earlier times.

Analyses of eukaryote genomes and protein sequences have also revealed relationships and times of divergence that have supported some models and challenged others. Molecular clocks support a relatively early origin of complex, multicellular life, at odds with some interpretations of the fossil record. Nonetheless, a time-based evolutionary tree of life (timetree of life), largely derived from genomic data, is coming into focus and it will be a great resource for understanding general principles of evolution, planetary habitability, and insights into life elsewhere.